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Ordering in Smectic Liquid Crystals Under Anisotropic Random Confinement

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Beamline(s): X22A

Introduction: We have initiated a study of smectic liquid crystals under the novel condition of anisotropic quenched disorder, which we create through confinement of the smectic in structurally anisotropic silica gels. Previous work characterizing the nematic to smectic-A transition in liquid crystals confined in aerogels and related porous media has demonstrated that the disorder introduced by the random environment can be accurately modeled in terms of random fields [1,2]. However, for such isotropic media the disorder couples both to the nematic director and to the smectic layering, and the coupling to the director is expected theoretically to be the dominant influence [2]. By contrast, a porous medium that energetically selects a globally preferred nematic orientation introduces random fields affecting solely the smectic order. The anisotropic gels in this study are designed to be realizations of such systems. Recent theories have predicted that Bragg glass phases should become stable in smectics with such anisotropic disorder [3]. Since a distinguishing feature of these exotic phases is the functional form of their smectic correlations, high-resolution x-ray scattering is the ideal probe to search for them.

Methods and Materials: The experimental samples consist of the thermotropic smectic liquid crystal octylcyanobiphenyl (8CB) and aerosil, nanometer-scale silica particles. When dispersed in 8CB, the aerosil forms a cross-linked hydrogen bonded gel. Due to elastic coupling between 8CB and the gel, repeated temperature cycling between the isotropic and nematic phases in a large magnetic field (H=2T) restructures the gel to accommodate the strongly aligned nematic. The modified silica structure is robust to removal of the field and subsequent temperature cycling so that the resulting sample represents a smectic confined in an anisotropic gel.

Results: The figure below shows results from X22A for the x-ray scattering intensity as a function of wave vector, $q_{||}$, parallel to the direction of the nematic alignment (i.e., the direction of previously applied H field) for a sample with silica density 0.1 g/cm^3 at several degrees below the nematic-smectic transition temperature in pure 8CB. The wider-than-resolution width of the smectic peak indicates the destruction of the quasi-long range order of the system. Also shown is the scattering intensity along the wave vector, $q_{\perp}$, perpendicular to the alignment direction which shows no signs of the peak and is considered background scattering from the gel structure. The inset shows the result of a rocking curve through the smectic peak. The width of the rocking curve provides a measure of the macroscopic nematic alignment induced by the gel, demonstrating a strongly preferred direction (easy axis) for nematic order. Analysis is underway to test for signatures of the predicted Bragg glass phase in this system.

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References:

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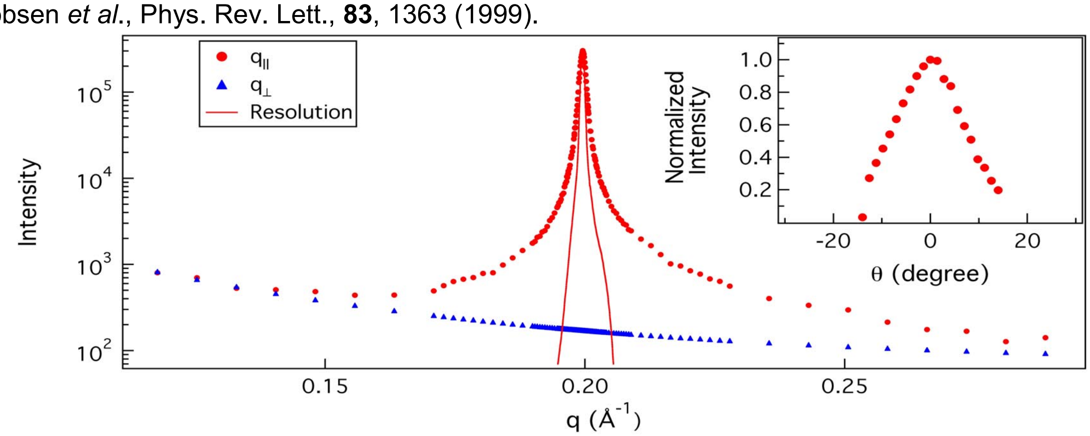

Figure. Scattering intensities as a function of wave vector q in the directions parallel (red dot) and perpendicular (blue triangle) to the nematic alignment for smectic 8CB in an anisotropic aerosil gel of density 0.1 g/cm^3. Also shown is the resolution (solid line) determined from the direct-beam profile. The inset shows the result of a rocking curve measurement through the smectic peak illustrating the quality of macroscopic nematic alignment imposed by the anisotropic gel.